habitat. Grassland protection will focus in particular on acquiring the largest remaining contiguous patches of unprotected grassland habitat, which are located south of State Route (SR) 4. This area connects to over 620 acres of existing habitat that was protected under the East Contra Costa County Habitat Conservation Plan (HCP)/ Natural Community Conservation Plan (NCCP) (East Contra Costa County Habitat Conservancy 2006). Refer to the CWF BA for siting details.

Western Yellow-Billed Cuckoo

DWR will offset the loss of 32 acres of western yellow-billed cuckoo migratory habitat through the creation or restoration at a 2:1 ratio, for a total of 64 acres of migratory riparian habitat creation or restoration in the action area. DWR will develop a riparian restoration plan that will identify the location and methods for riparian creation or restoration, and this plan will be subject to Service approval. Refer to the CWF BA for further discussion.

Giant Garter Snake

Where identified and delineated giant garter snake habitat cannot be avoided, compensation for the loss of the habitat will occur at a ratio of 3:1 for each, aquatic and upland habitat. An estimated 775 acres of giant garter snake habitat will be affected; therefore, approximately 2,325 acres of giant garter snake habitat will be protected or restored. Insofar as mitigation is created/protected in a Service agreed-to high-priority conservation area, such as the eastern protection area between Caldoni Marsh and Stone Lakes, a mitigation ratio of 2:1 for each, aquatic and upland habitat type, will apply which may lower the above example to 1,550 acres of mitigation. This ratio and locations will be reviewed and approved by the Service.

Giant garter snake upland mitigation will be placed and protected adjacent to aquatic habitat protected for giant garter snake. The upland habitat will not exceed 200 ft from protected aquatic habitat (unless research shows a larger distance is appropriate and the Service agrees).

Incidental injury and/or mortality of giant garter snakes within protected and restored habitat will be avoided or minimized by establishing 200-ft buffers between protected giant garter snake habitat and roads (other than those roads primarily used to support adjacent cultivated lands and levees). Protected and restored giant garter snake habitat will be at least 2,500 ft from urban areas or areas zoned for urban development.

Characteristics of restored and protected habitat may change from the above descriptors if new information and best available science indicate greater benefits as agreed to by the Service. Specific mitigation locations have not been proposed at this time. Siting criteria as described in the CWF BA are still in discussion between DWR, the Service, and CDFW.

California Red-Legged Frog

California red-legged frog aquatic and upland habitat will be protected at a ratio of 3:1 within the East San Francisco Bay core recovery area, at locations subject to Service approval. Three acres of aquatic habitat and 153 acres of upland cover and dispersal habitat will be protected. The compensation ratios apply only if protection occurs prior to or concurrent with the impact. If protection occurs after an impact, the ratio will increase. Refer to the CWF BA for further discussion.

California Tiger Salamander

DWR will protect California tiger salamander habitat at a ratio of 3:1 at locations subject to Service approval, adjacent to or near occupied, protected upland habitat, with a management plan and endowment, or similar funding mechanism, to direct and fund management in perpetuity. California tiger salamander habitat protection will be located in the Byron Hills area, west of the worksite. Grasslands targeted for protection will be located near important areas for conservation that were identified in the East Contra Costa County HCP/NCCP (East Contra Costa County Habitat Conservancy 2006) (not all of which will be acquired by that plan) and will include appropriate upland and aquatic features, *e.g.*, rodent burrows, stock ponds, intermittent drainages, and other aquatic features, etc. An estimated 150 acres of habitat will be protected. Refer to the CWF BA for further discussion.

Valley Elderberry Longhorn Beetle

DWR will mitigate impacts to valley elderberry longhorn beetle habitat by either creating valley elderberry longhorn beetle habitat or by purchasing the equivalent credits at a Service-approved conservation bank with a service area that overlaps with the action area consistent with the 1999 Valley Elderberry Longhorn Beetle Conservation Guidelines. These guidelines require replacement of each impacted valley elderberry bush stem measuring one inch or greater in diameter at ground level, in the Conservation Area, with valley elderberry seedlings or cuttings at a ratio ranging from 1:1 to 8:1 (new plantings to affected stems), and planting of associated native riparian plants. These ratios will apply if compensation occurs prior to or concurrent with the impacts. If compensation occurs after the impacts, a higher ratio may be required by the Service. The planting area will provide at a minimum 1,800 square feet (sf) for each transplanted valley elderberry shrub. As many as five additional valley elderberry plantings (cuttings or seedlings) and up to five associated native species plantings may also be planted within the 1,800 square ft area with the transplant. An additional 1,800 sf will be provided for every additional 10 conservation plants. Refer to the CWF BA for further discussion.

Vernal Pool Fairy Shrimp and Tadpole Fairy Shrimp

For every acre of habitat directly or indirectly affected, at least two vernal pool credits will be purchased within a Service-approved ecosystem preservation bank. Alternatively, based on Service evaluation of site-specific conservation values, three acres of vernal pool habitat may be preserved at the affected site or on another non-bank site as approved by the Service. For every acre of habitat directly affected, at least one vernal pool creation credit will be dedicated within a Service-approved habitat conservation bank, or, based on Service evaluation of site-specific conservation values, two acres of vernal pool habitat will be created and monitored at the affected site or on another non-bank site as approved by the Service.

Compensation ratios for non-bank compensation may be adjusted if the Service considers the conservation value of the non-bank compensation area to approach that of Service-approved conservation banks. If protection occurs outside a Service-approved conservation bank, protection will be prioritized in the Livermore recovery unit, which is one of the core recovery areas identified in the Vernal Pool Recovery Plan (Service 2005) and is adjacent to an existing protected vernal pool complex. Protected sites will be prioritized within the affected critical habitat unit for vernal pool fairy shrimp, unless an adequate rationale is provided to the Service for lands to be protected outside of the critical habitat unit. Protected sites will include the surrounding upland watershed necessary to sustain the vernal pool functions (*e.g.*, hydrology, uplands to provide for pollinators, etc.).

If vernal pool restoration is conducted outside of a Service-approved conservation bank, the restoration sites will meet the following site selection criteria: (1) the site has evidence of historical vernal pools based on soils, remnant topography, remnant vegetation, historical aerial photos, or other historical or site-specific data, (2) the site supports suitable soils and landforms for vernal pool restoration, (3) the adjacent land use is compatible with restoration and long-term management to maintain natural community functions (*e.g.*, not adjacent to urban or rural residential areas), and (4) ensure sufficient land is available for protection (vernal pool features and surrounding grasslands) to ensure the local watershed can sustain vernal pool hydrology, with a vernal pool density representative of intact vernal pool complex in the vicinity of the restoration site.

Acquisition of vernal pool restoration sites will be prioritized based on the following criteria: (1) the site will contribute to establishment of a large, interconnected vernal pool and alkali seasonal wetland complex reserve system (*e.g.*, adjacent to an existing protected vernal pool complex or alkali seasonal wetland complex) and (2) the site is close to known populations of vernal pool fairy shrimp or vernal pool tadpole shrimp. Refer to the CWF BA for further discussion.

Least Bell's Vireo

DWR will mitigate the loss of 32 acres of least Bell's vireo habitat through the creation or restoration at a 2:1 ratio, for a total of 64 acres of riparian habitat creation or restoration in the action area. DWR will develop a riparian restoration plan that will identify the location and methods for riparian creation or restoration, and this plan will be subject to Service approval.

Sacramento River Sediment Reintroduction

Sacramento River sediment removed from the water column at the intake sedimentation basins will be reused. To the maximum extent practicable, the first and preferred disposition of this material will be to reintroduce it to the water column in order to maintain Delta water quality (specifically, turbidity, as a component of delta smelt critical habitat). DWR will collaborate with the Service and CDFW to develop and implement a sediment reintroduction plan that provides the desired beneficial habitat effects of maintained turbidity while addressing related permitting concerns (the proposed sediment reintroduction is expected to require permits from the Central Valley Regional Water Quality Control Board and the Corps). The Service and NMFS will have approval authority for this plan and for monitoring measures, to be specified in the plan, to assess its effectiveness. Current conceptual design for the plan suggests that it will incorporate placement of sediment during low flow periods at a seasonally inundated location along the mainstem river, such as a bench constructed for the purpose. The sediment would then be remobilized and carried downstream following inundation during seasonal high flows (generally, the winter and spring months). The sediment reintroduction would be designed for consistency with CVRWQCB's Basin Plan objectives for turbidity, namely, "For Delta waters, the general objectives for turbidity apply subject to the following: except for periods of storm runoff, the turbidity of Delta waters shall not exceed 50 NTUs (Nephelometric Turbidity Units) in the waters of the central Delta and 150 NTUs in other Delta waters. Exceptions to the Delta specific objectives will be considered when a dredging operation can cause an increase in turbidity. In this case, an allowable zone of dilution within which turbidity in excess of limits can be tolerated will be defined for the operation and prescribed in a discharge permit" (Central Valley Water Board 1998).

7.0 DESCRIPTION OF THE ACTION AREA

The action area is defined in 50 CFR § 402.02, as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action." The action area for this consultation encompasses the entire legal Delta, Suisun Marsh, Suisun Bay, and Byron Hills; and extends upstream within the channels of the Sacramento and American rivers to Keswick and Nimbus Dams. See Figure 7.0-1 and 7.0-2. Byron Hills is 13,156 acres south of Highway 4, east of Los Vaqueros Reservoir, north of the Contra Costa/Alameda county line, and west of the Byron Highway.

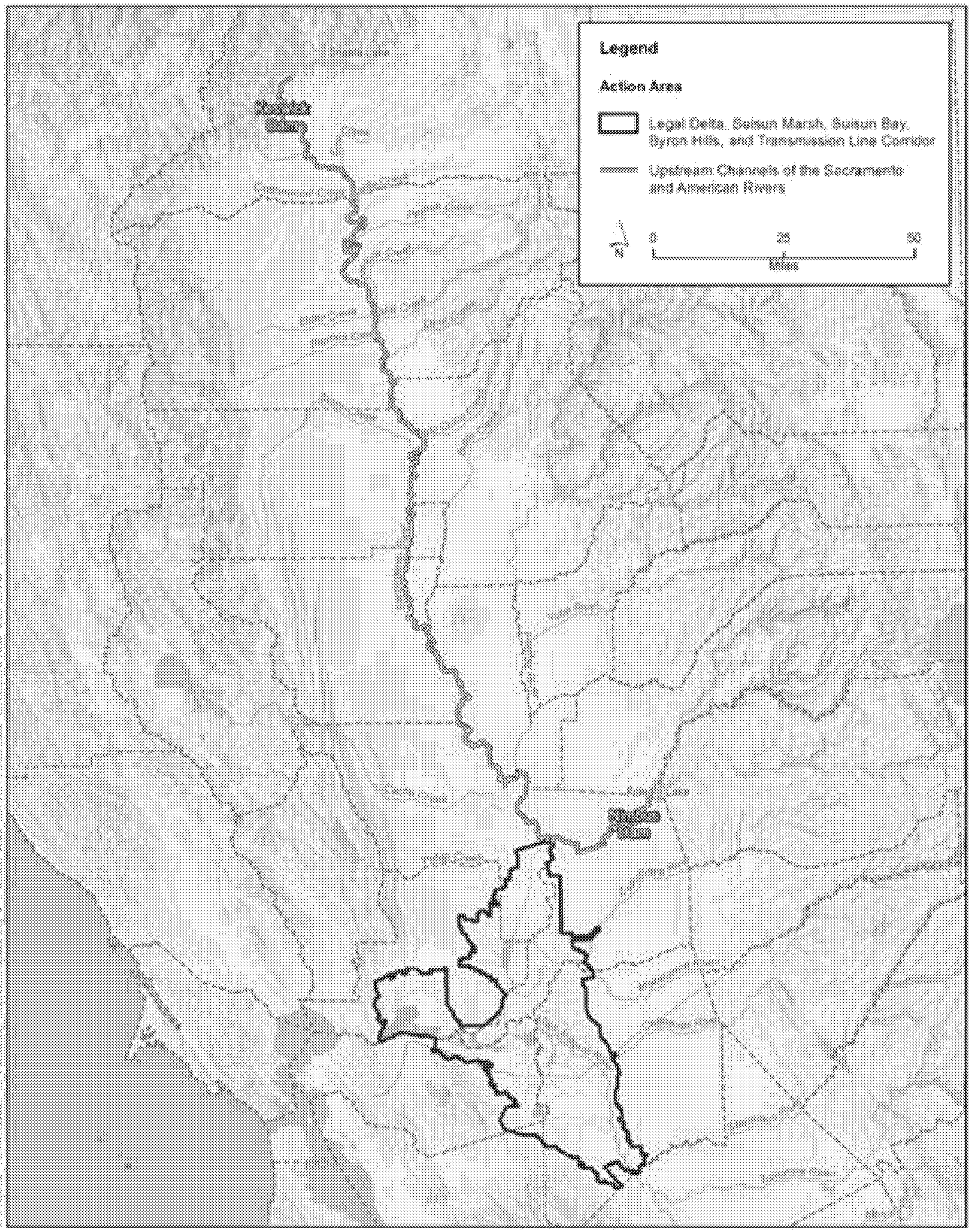

Figure 7.0-1. Map of CWF Action Area.

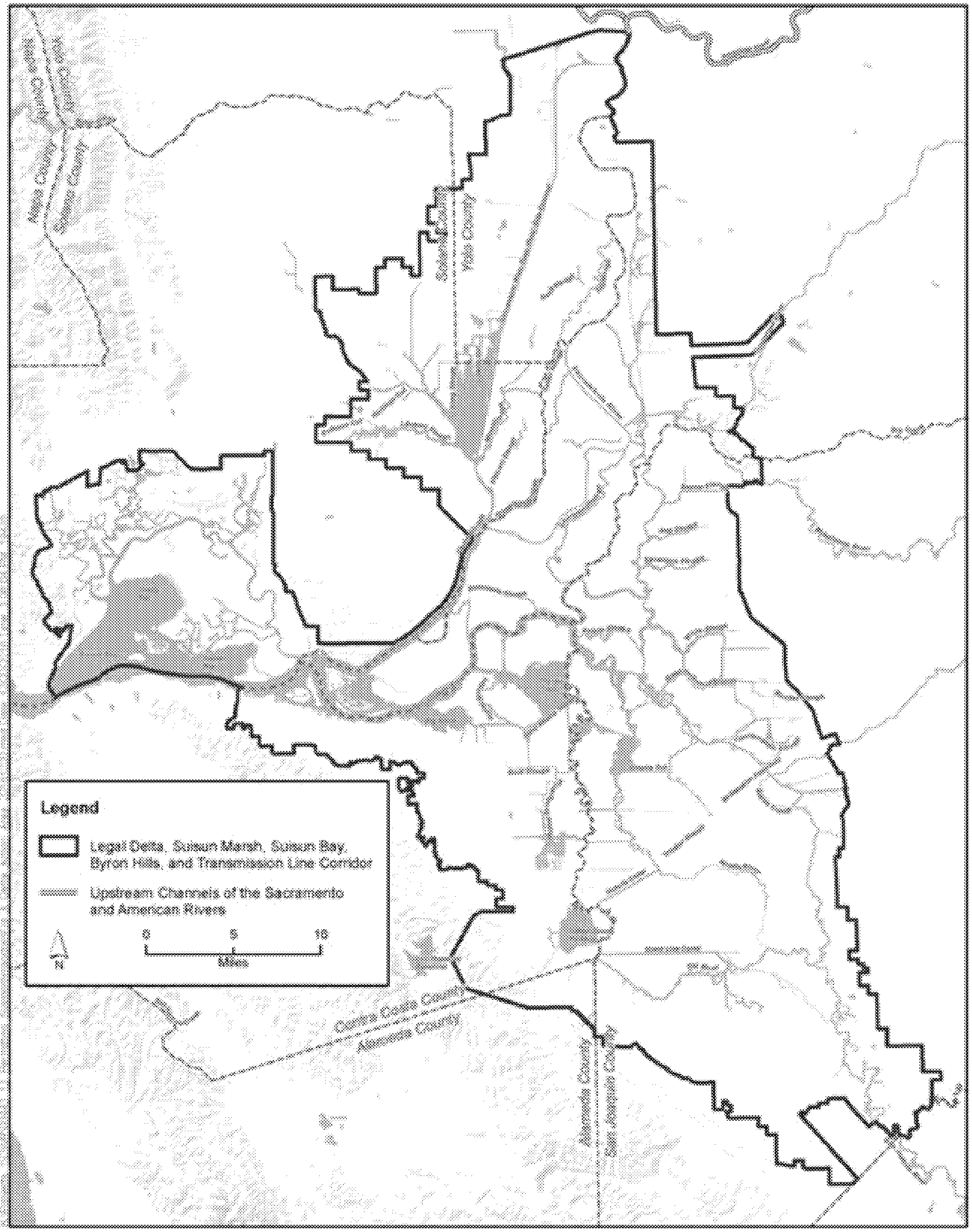

Figure 7.0-2. Detailed map of CWF Action Area.

8.0 ANALYTICAL FRAMEWORK

8.1 Analytical Framework for the Jeopardy Determination

Section 7(a)(2) of the Act requires that Federal agencies ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of listed species. "Jeopardize the continued existence of" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR § 402.02).

The jeopardy analysis in this BiOp considers the effects of the proposed Federal action, and any cumulative effects, on the range-wide survival and recovery of the listed species. It relies on four components: (1) the *Status of the Species*, which describes the range-wide condition of the species, the factors responsible for that condition, and its survival and recovery needs, (2) the *Environmental Baseline*, which analyzes the condition of the species in the action area, the factors responsible for that condition, and the relationship of the action area to the survival and recovery of the species, (3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed Federal action and the effects of any interrelated or interdependent activities on the species, and (4) the *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on the species.

8.2 Analytical Framework for the Adverse Modification Determination

Section 7(a)(2) of the Act requires that Federal agencies insure that any action they authorize, fund, or carry out is not likely to destroy or to adversely modify designated critical habitat. A final rule revising the regulatory definition of "destruction or adverse modification" was published on February 11, 2016 (81 FR 7214). The final rule became effective on March 14, 2016. The revised definition states:

> "Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features."

The destruction or adverse modification analysis in this BiOp relies on four components: (1) the *Status of Critical Habitat*, which describes the range-wide condition of the critical habitat in terms of the key components (*i.e.*, essential habitat features, primary constituent elements, or physical and biological features) that provide for the conservation of the listed species, the factors responsible for that condition, and the intended value of the critical habitat overall for the conservation/recovery of the listed species, (2) the *Environmental Baseline*, which analyzes the condition of the critical habitat in the action area, the factors responsible for that condition, and the value of the critical habitat in the action area for the conservation/recovery of the listed species, (3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed Federal action and the effects of any interrelated and interdependent activities on the key components of critical habitat that provide for the conservation of the listed species, and how those impacts are likely to influence the conservation value of the affected critical habitat, and (4) *Cumulative Effects*, which evaluate the effects of future non-Federal activities that are reasonably certain to occur in the action area on the key components of critical habitat that provide for the conservation of the listed species and how those impacts are likely to influence the conservation value of the affected critical habitat.

For purposes of making the destruction or adverse modification determination, the Service evaluates if the effects of the proposed Federal action, taken together with cumulative effects, are likely to impair or preclude the capacity of critical habitat in the action area to serve its intended conservation function to an extent that appreciably diminishes the range-wide value of critical habitat for the conservation of the listed species. The key to making that finding is understanding the value (*i.e.*, the role) of the critical habitat in the action area for the conservation/recovery of the listed species based on the *Environmental Baseline* analysis.

9.0 SPECIES ANALYSES

9.1 Considerations Applicable to All Species

The PA includes activities at various stages of development, for which little or no information exists at this time regarding effects to listed species or critical habitat. These activities include compensatory mitigation, maintenance of the proposed facilities, monitoring, and adaptive management of several aspects of the PA. Pursuant to the *Consultation Approach* section above, Reclamation or the Corps will ensure that effects to species or critical habitat are addressed by either reinitiating this consultation or initiating subsequent consultations, depending on the triggers and processes associated with each activity.

Compensatory Mitigation

DWR proposes to provide species-specific compensatory mitigation prior to construction, operations, and other activities at the ratios or acreages identified in the *Description of the Proposed Action* for each species. DWR has proposed to use one or more of the following options to implement the species-specific mitigation: (1) restoration with protection in perpetuity, (2) enhancement with protection in perpetuity, (3) purchasing credits at an approved conservation bank, (4) creating and establishing a conservation bank, and (5) protection in perpetuity without restoration or enhancement. We anticipate that this compensatory mitigation will minimize effects to each species by replacing the function of the habitat lost, altered, or degraded as a result of construction, maintenance, and operations of the existing and proposed CVP and SWP facilities in the action area, unless otherwise specifically identified in the species-specific effects sections. DWR has proposed to develop and implement management plans for the mitigation lands, but has not yet identified specific sites. The CWF BA does not identify or analyze effects to listed species or critical habitat from implementation of the compensatory mitigation because, the mitigation sites have not been chosen. Without the site-specific information will mitigation will be located, we don't have sufficient information to determine if mitigation will have species effects or the extent of those effects.

All compensatory mitigation activities will be subject to approvals by either Reclamation or the Corps (as described in the *Description of the Proposed Action*), depending on the nature of the activity and which agency has authority and oversight. Therefore, either reinitiation of this consultation or subsequent consultations with either of these agencies will occur so that the Service can assess the effects of each compensatory mitigation project.

For activities under the Corps' Phase 1 permitting process, if it is determined that listed species or critical habitat are present and may be affected as a result of the compensatory mitigation, the Corps will reinitiate this consultation to address these effects. Effects of the compensatory mitigation associated with the Corps Phase 2 and Reclamation's actions will be addressed in subsequent consultations.

The action agencies and DWR have committed in the PA to protecting and managing mitigation sites in perpetuity and ensuring adequate funding for the perpetual management of all compensatory mitigation. Management plans will be developed for each compensatory mitigation site with a conservation easement or other Service-approved conservation mechanism that is held by a third party approved by the Service. DWR will secure an endowment or other Service-approved financial assurance that will be sufficient to fund any monitoring, operations, maintenance, and adaptive management of the restoration site. Further, the endowment or other Service-approved financial assurance will designate the party or entity that will be responsible for the long-term management of these lands and associated waterways as applicable. The Service will be provided with written documentation that funding and management of mitigation lands will be provided in perpetuity.

Therefore, based on these commitments and assurances provided by DWR described in the CWF BA, we anticipate that the proposed compensatory mitigation will minimize the adverse effects of PA activities to each species by replacing the function of the habitat that will be lost, altered, or degraded as a result of implementing the PA. Where appropriate, the proposed species-specific habitat ratios or acreages are described within our analysis of each species.

Maintenance

As described in the *Description of the Proposed Action*, future maintenance of the project facilities will be necessary. Table 9.1-1 describes some of the anticipated maintenance activities and their assumed frequencies once the facilities are built. Little information is known at the time of this consultation about when, how, and, in some cases, where these maintenance activities will be implemented; therefore, no analysis was provided in the CWF BA as to how or if these activities would affect listed species or critical habitat. Addressing effects resulting from future maintenance activities would be speculative at this time. If maintenance activities may affect listed species or critical habitat and are not subject to future approvals (*i.e.*, the Corps' Phase 1 permit), reinitiation of this consultation is required to address those effects. Maintenance activities associated with all other aspects of the PA will require future approvals as described in the *Description of the Proposed Action* and will be subject to future consultations if those activities may affect listed species or critical habitat.

Table 9.1-1. Potential maintenance activities and assumed frequency associated with elements of the PA as described in the CWF BA.

North Delta Diversions

Activity	Assumed Frequency	
	Basic	Major
Dredging within sedimentation basins in areas isolated from river	Annually	
Dredging on river side of intake screen	Every 3-5 years (routine maintenance dredging)	Every 10-15 years based on frequency of flow events (>100,000 cfs)
Levee maintenance (responsibility transferred to Corps or Central Valley Flood Protection Board [CVFPB])	-Inspections: 4x/year (no more than 90 days apart) -Vegetation control: 2x/year -Approx. 20 days/year total -Assume maintenance occurs within 100 ft distance from intake structure	Dependent on major erosion or other stability issues
Fish screen and bay maintenance activities in areas isolated from river	Weekly inspections for normal operation of screens and cleaning system	Annual maintenance of fish screen (pressure washing) and bays (dewatering, sediment/debris removal, and mechanical maintenance)
Cleaning brush replacement	Annual inspections	Replacement (typically every 3 years)
Baffle adjustment	Tuning to achieve uniform approach velocity across screen face annually	As needed to comply with design/screening criteria
Debris removal (log boom, screen face) on river side of intake screen	Annually or as needed	
Inspection, maintenance, and monitoring of screen	Keep maintenance log	

Clifton Court Forebay

Activity	Assumed Frequency	
	Basic	Major
Dredging of SCCF	Minimum of every 15 years	Unanticipated; potential dredging to address shoaling/scouring affecting gate operations
Embankment maintenance (per Division of Safety of Dams [DSOD] requirements)	-Inspections: 4x/year -Vegetation control: 2x/year -Approx. 20 days/year total	Frequency of repairs dependent on major erosion/stability issues
Vegetation control	Annually in summer (2-3 days per treatment)	
Predator control	Boat electrofishing: 3x/week (Jan-May)	
Labyrinth weir debris removal	None if not used	Periodically as weir is used for emergency overflow
Siphon	Debris removal annually or as needed	Sediment removal in siphon
Debris removal (roller gates, radial gates, stop logs)	Annually or as needed	

Barge Landings

Activity	Assumed Frequency	
	Basic	Major
Dredging	Every 3-5 years after initial dredging (depending on lifespan of landing)	Spot dredging as needed to address potential grounding issues
Barge route dredging	Every 3-5 years after initial dredging (depending on duration of barge operations)	Spot dredging as needed to address potential grounding issues
Aquatic vegetation control	Annual inspections; spot treat annually or as needed	

Head of Old River Gate

Activity	Assumed Frequency	
	Basic	Major
Dredging	Every 3-5 years (routine maintenance dredging)	-Removal of accumulated sediment after major flow events: Every 5-10 years based on Vernalis flows > 30,000 cfs -Spot dredging as needed to address potential grounding issues
Mechanical maintenance (motors, compressors, control systems)	-Annual inspections; servicing/repairs as needed	
Gate maintenance (Obermeyer-type gate assumed)	-Annual inspections; servicing/repairs as needed -Monthly testing of gate mechanism -Sediment/debris removal: Annually or as needed	Dewatering and repairs: Every 5-10 years
Boat lock maintenance	-Annual inspections; servicing/repairs as needed -Monthly testing of gate mechanism -Sediment/debris removal: Annually or as needed -Aquatic vegetation control: Annual inspections and treatment as needed	Dewatering and repairs: Every 5-10 years
Fish ladder maintenance	Maintain water surface elevation levels when the gate is in operation	-Annually or as needed (more frequent during winter months) -Sediment/debris removal after major flow events

Compensatory Mitigation Sites

Activity	Assumed Frequency	
	Basic	Major
Levee maintenance (responsibility transferred to local maintenance agencies)	Inspections: 4x/year Vegetation control: 2x/year Approx. 20 days/year total	
Riparian plantings (replantings, watering, non-native removal)	Watering: 2x/week (summer) and 2x/month (growing season) for 2-3 years Non-native removal: 1x/2 months for 3-5 years	Annual inspections and applied treatments as necessary
Post-project habitat monitoring	After success criteria are achieved, inspections conducted once every 3-5 years to verify functionality and compliance with performance standards	Once per month for first 2 years
Aquatic species and water quality monitoring	Once per month for species of interest for years 1-3	Annually for years 4-10
Terrestrial species and delta smelt monitoring	Future Service-approved long-term management and monitoring plan with future identified performance standards	

Monitoring

Monitoring activities will occur prior to operations and after operations commence. Monitoring and studies of listed fish species will be focused on the construction and operation of conveyance facilities. This monitoring will begin with baseline data collection needed to compare with similar post-construction findings. While a detailed effort has been made regarding proposed monitoring for the NDD, monitoring prior to operations will be required throughout the action area. DWR has committed to working with the Service and other agencies to develop the specifics (including timeframes) of monitoring using various technical teams. Monitoring and studies related to operations that must occur after operation of the new facilities has commenced consist of four types: monitoring addressing the operation of the proposed new facilities, monitoring related to species condition and habitat that may be influenced by operations of the new facilities, monitoring to evaluate the effectiveness of the proposed facilities, and monitoring addressing the performance of the habitat protection and restoration sites.

Little information is known at the time about when, where, and how monitoring will be implemented; therefore, no analysis was provided in the CWF BA as to how these activities would affect listed species or critical habitat. Addressing effects resulting from monitoring activities would be speculative at this time. If monitoring activities that are not subject to future section 7 consultation or approvals (*i.e.*, the Corps' Phase 1 permit) may affect listed species or critical habitat, reinitiation of this consultation is required to address those effects. Monitoring activities associated with all other aspects of the PA will require future approvals as described in the *Description of the Proposed Action* and will be subject to future consultations if those activities may affect listed species or critical habitat.

Adaptive Management

Reclamation, DWR, the Service, NMFS, CDFW, and the public water agencies have agreed to develop a program of collaborative science, monitoring, and adaptive management in support of CWF (CWF BA 2016, Appendix 3.H). The AMP outlines a collaborative process for assessing and adapting to effects to listed species stemming from the ongoing operation of the CVP and SWP, including future implementation and operation of the CWF. Under the AMP, new information developed during the course of implementation is expected to inform operational decisions and conservation tactics. New information will be developed through scientific research to understand the ecological changes that the CWF and other cumulative effects will have on the Bay-Delta ecosystem, including delta smelt. However, currently little information is known about what, when, where, and how these effects will be adaptively managed, much less how they will be implemented. Therefore, no analysis was provided in the CWF BA as to how or if activities associated with adaptive management would affect listed species or critical habitat. Addressing effects resulting from the implementation of the adaptive management plan would be speculative at this time. If activities that are identified as part of the framework are not subject to future approvals (*i.e.*, the Corps' Phase 1 permit) and may affect listed species or critical habitat, reinitiation of this consultation is required to address those effects. Activities associated with all other aspects of the PA will require future approvals as described in the *Description of the Proposed Action* and will be subject to future consultations if those activities may affect listed species or critical habitat.

9.2 Delta Smelt and its Critical Habitat

9.2.1 Status of the Species and Critical Habitat/Environmental Baseline

The CWF action area encompasses almost the entire species range and the critical habitat designation. The Napa River is outside of the CWF action area, but delta smelt do occur in that river. However, this small area is on the fringe of the species range. For the purposes of this BiOp, the Status of the Species, Status of the Critical Habitat, and Environmental Baseline are combined.

The Environmental Baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the Action Area that have already undergone formal or early section 7 consultation, and the impact of State or private actions, which are contemporaneous with the consultation in process (50 CFR 402.02). The key purpose of the Environmental Baseline is to describe the condition of the listed species/critical habitat that exist in the action area in the absence of the action subject to this consultation. Sections 9.2.1.2 and 9.2.1.4 describe in more detail the conditions in the action area and a description of previous actions that have contributed to these current conditions.

9.2.1.1 Status of the Species

Legal Status

The Service proposed to list the delta smelt (*Hypomesus transpacificus*) as threatened with proposed critical habitat on October 3, 1991 (Service 1991). The Service listed the delta smelt as threatened on March 5, 1993 (Service 1993), and designated critical habitat for the species on December 19, 1994 (Service 1994). The delta smelt was one of eight fish species addressed in the *Recovery Plan for the Sacramento–San Joaquin Delta Native Fishes* (Service 1996), and a revision addressing delta smelt is currently underway. A 5-year status review of the delta smelt was completed on March 31, 2004 (Service 2004). The 2004 review concluded that delta smelt remained a threatened species. A subsequent 5-year status review recommended uplisting delta smelt from threatened to endangered (Service 2010a). A 12-month finding on a petition to reclassify the delta smelt as an endangered species was completed on April 7, 2010 (Service 2010b). After reviewing all available scientific and commercial information, the Service determined that re-classifying the delta smelt from a threatened to an endangered species was warranted but precluded by other higher priority listing actions (Service 2010c). The Service annually reviews the status and uplisting recommendation for delta smelt during its Candidate Notice of Review (CNOR) process. Each year, the CNOR has recommended the uplisting from threatened to endangered. Electronic copies of these documents are available at http://ecos.fws.gov/docs/five_year_review/doc3570.pdf and http://www.gpo.gov/fdsys/pkg/FR-2013-11-22/pdf/2013-27391.pdf (Service 2010a; Service 2010b).

Description and Life Cycle

The delta smelt is a small fish of the family Osmeridae. It is endemic to the San Francisco Bay-Delta where it primarily occupies open-water habitats in Suisun Bay and marsh and the Sacramento-San Joaquin Delta. The delta smelt is primarily an annual species, meaning that it completes its life cycle in one year which typically occurs from April to the following April plus or minus one or two months. In captivity delta smelt can survive to spawn at two years of age (Lindberg *et al.* 2013), but this appears to be rare in the wild (Bennett 2005). Very few individuals reach lengths over 3.5 inches (90 mm).

Population Numbers

The spawning stock of delta smelt in WY 2017 appears to be at its second lowest abundance on record, the lowest having been recorded during WY 2016 (Table 9.2.1.1-1). The 2016 Fall Midwater Trawl (FMWT) Index was 7, the second lowest on record. The CDFW Spring Kodiak Trawl (SKT) monitors the adult spawning stock of delta smelt and serves as an indication for the relative number and distribution of spawners in the system. The 2017 SKT Abundance Index is 3.8, the second lowest on record. The Service calculated an absolute abundance estimate[18] for adult delta spawners in WY 2017, using January and February SKT data. This absolute abundance estimate is also the second lowest on record (Table 9.2.1.1-1). The population size of adult delta smelt January through February 2017 was estimated to be between 22,000 and 92,000 fish with a point estimate of 47,786. The January through February, 2016 point estimates were the lowest values since 2002 and suggested delta smelt experienced increased mortality during the extreme drought conditions occurring during 2013-2015. While 2017 estimates likely represent an increase in recruitment and survival from the prior year, the continued low parental stock of delta smelt relative to historical numbers suggest the population will continue to be vulnerable to stochastic events and operational changes that may occur in response until successive years of increased population growth results in a substantial increase in abundance.

[18] The Service completed a revised adult delta smelt abundance estimation procedure based on CDFW's SKT data for January and February (see Table 9.2.1.1-1). This procedure has recently been updated from that used in 2016. While these estimates likely represent a minimum population size due to the method reliance on survey data, this is our current best estimate of the annual population size.

Table 9.2.1.1-1. Three indicators of adult delta smelt status for WYs 2002-2017. Column 2 is the CDFW FMT Index by WY (*i.e.*, the indices for calendar years 2001-2016). Column 3 is the CDFW SKT Index. Column 4 is an estimate of adult delta smelt abundance during January and February that the Service calculates from the SKT survey. The SKT Index will not be available until June 2017.

WY	FMWT Index (unitless)	SKT Index (unitless)	January and February SKT Abundance Estimate (number of delta smelt) [Lower; Upper Confidence Interval]
2002	603	N/A	739,877 [506,889; 1,043,891]
2003	139	N/A	634,000 [340,811; 1,081,388]
2004	210	99.7	654,492 [370,200; 1,074,662]
2005	74	52.9	477,775 [308,015; 708,388]
2006	26	18.2	186,797 [133,663; 254,133]
2007	41	32.5	291,964 [155,148; 502,239]
2008	28	24.1	325,333 [147,533; 626,188]
2009	23	43.8	365,946 [151,439; 748,841]
2010	17	27.4	169,417 [106,837; 255,665]
2011	29	18.8	290,792 [99,502; 670,574]
2012	343	130.2	772,311 [420,904; 1,303,955]
2013	42	20.4	212,504 [95,804; 410,659]
2014	18	30.1	207,595 [110,373; 356,969]
2015	9	13.8	139,310 [66,314; 259,301]
2016	7	1.8	16,159 [7,403; 30,886]
2017	8	3.8	47,786 [21,709; 91,864]

In addition to these abundance estimates, the CDFW conducts four fish surveys from which it develops indices of delta smelt's relative abundance (Figures 9.2.1.1-1 and 9.2.1.1-2). Each survey has variable and unquantified capture efficiency, and in each, the frequency of zero catches of delta smelt is very high, largely due to the species' rarity (*e.g.*, Latour 2016; Polansky *et al.* in press). The [summer] Townet Survey (TNS) is the longest running indicator of delta smelt relative abundance; it has been conducted since 1959. Although this survey was designed to index the relative abundance of metamorphosing juvenile striped bass (*Morone saxatilis)* (Turner and Chadwick 1972), delta smelt have been collected incidentally; most of the delta smelt captured are age-0 and about 20-40 mm in length (Miller 2000). The FMWT is the second longest running indicator of delta smelt relative abundance; it has been conducted since 1967. This survey was also designed to index the relative abundance of age-0 striped bass (Stevens 1977), but as with the TNS, delta smelt are collected incidentally (Stevens and Miller 1983). Most of the delta smelt captured by the FMWT are age-0 "subadults" and are about 50-70 mm in length (Sweetnam 1999). The 20-mm Survey is the third longest running indicator of delta smelt relative abundance; it has been conducted since 1995. This survey was designed to monitor the distribution of late larval or metamorphosing juvenile delta smelt to assess their distribution and risk of entrainment into the large water export diversions of the CVP and SWP (Dege and Brown 2004). As its name suggests, most of the delta smelt collected by the 20-mm Survey are about 10-30 mm in length, with a peak catch of fish just under 20 mm (Kimmerer 2008). The newest indicator of delta smelt relative abundance is the SKT Survey, which has been conducted since 2002. This survey was designed to monitor the distribution of pre-spawn and spawning adult delta smelt to assess their distribution and risk of entrainment. Most of the delta smelt captured in the SKT are 60-80 mm in length (Bennett 2005).

The TNS and FMWT abundance indices for delta smelt have documented the species' long-term decline, while the newer 20-mm and SKT abundance indices have generally confirmed the recent portions of the trends implied by the older surveys (Figures 9.2.1.1-1 and 9.2.1.1-2). During the period of record, juvenile delta smelt relative abundance has declined from peak levels observed during the latter 1970s (Figure 9.2.1.1-1), while subadult relative abundance was at its highest in 1970, and similarly high in 1980 (Figure 9.2.1.1-2). Juvenile and subadult abundance indices both declined rapidly during the early 1980s, increased somewhat during the 1990s, and then collapsed in the early 2000s. Since 2005, the TNS and the FMWT have produced indices that reflect less year to year variation than their 20-mm and SKT analogs, but overall, the trends in both sets of indices are similar. During the past decade, each index has frequently reached new record low levels. The TNS index was 0.0 in 2015 and 2016, and the 2015 FMWT index and subsequent 2016 SKT index were record lows (about one half of one percent of the relative abundance recorded in 1970-1971).

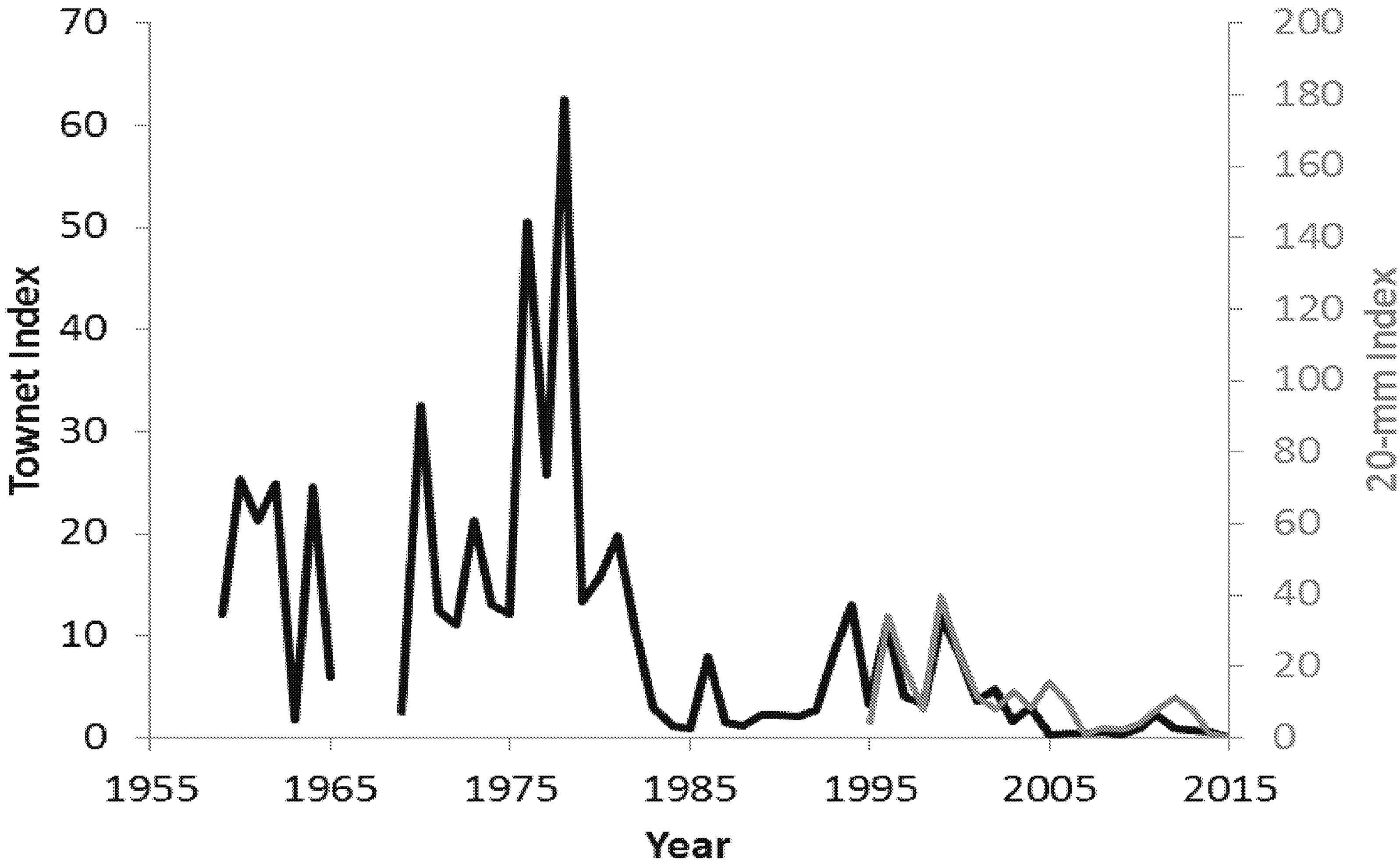

Figure 9.2.1.1-1. Time series of the CDFW's summer TNS (black line; primary y-axis) and 20-mm Survey (gray line; secondary y-axis) abundance indices for delta smelt.

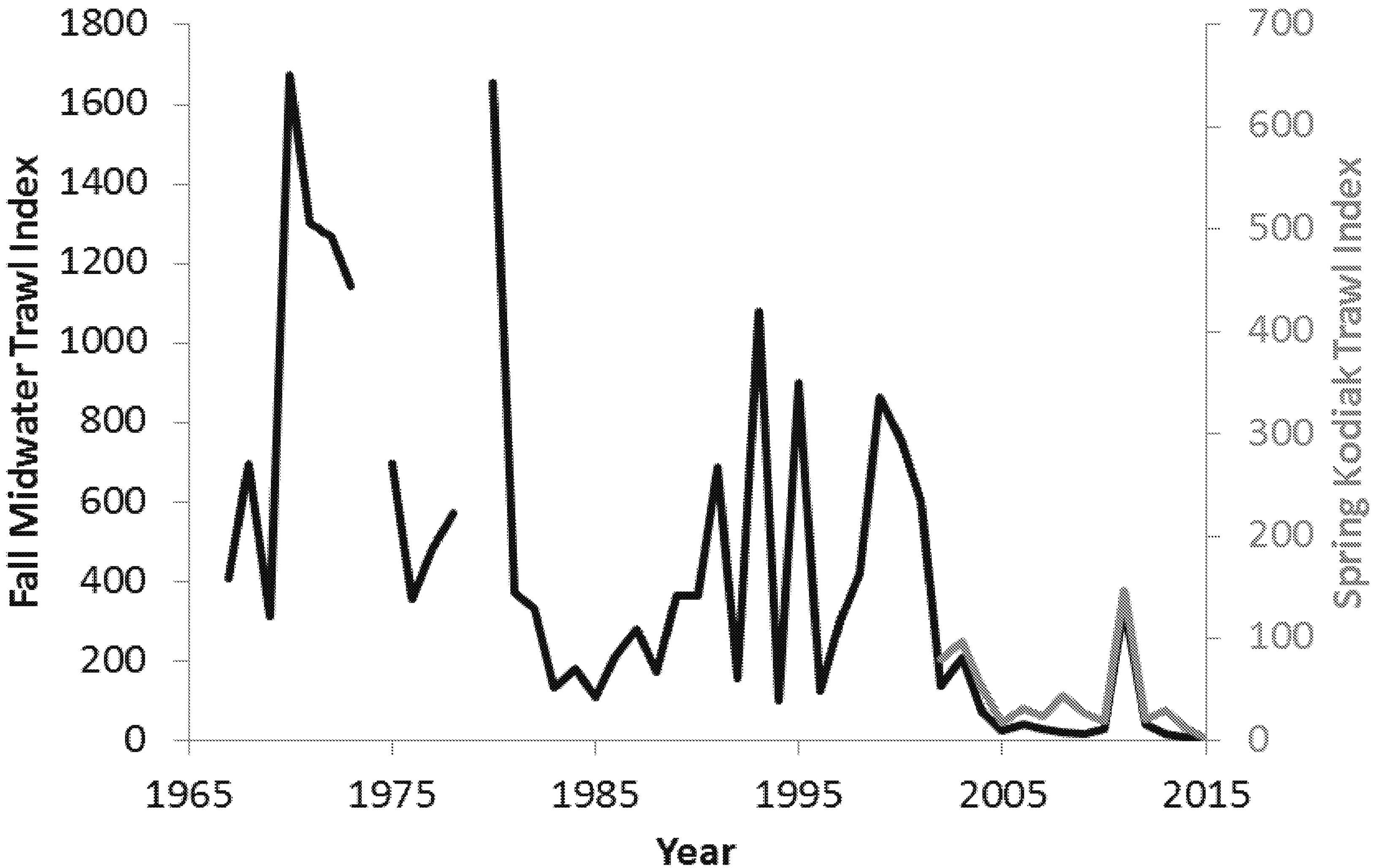

Figure 9.2.1.1-2. Time series of the CDFW's FMWT (black line; primary y-axis) and SKT (gray line; secondary y-axis) abundance indices for delta smelt.

The abundance of adult delta smelt may have exceeded twenty million in 1980-1981 (Rose *et al.* 2013b). This may sound like a large number – and it is compared to the contemporary estimates listed in Table 9.2.1.1-1. However, decades of monitoring by CDFW has shown that the delta smelt has usually not been very abundant when compared to other pelagic (meaning offshore-oriented or open-water) fishes (Figure 9.2.1.1-3). In the TNS, delta smelt catches have usually been lower than age-0 striped bass, and in recent years, also lower than gobies and threadfin shad. In the FMWT, delta smelt catches have been persistently lower than at least five other species. Research and monitoring in shallower habitats like Suisun Marsh (Moyle *et al.* 1986; Matern *et al.* 2002), Delta beaches (Nobriga *et al.* 2005), and small tidal marshes in the upper estuary (Gewant and Bollens 2012) have reported even lower relative abundances of delta smelt. In each of the studies cited, the catches of delta smelt represented less than one percent of the total fish catch and there were usually more than a dozen more abundant fish species.

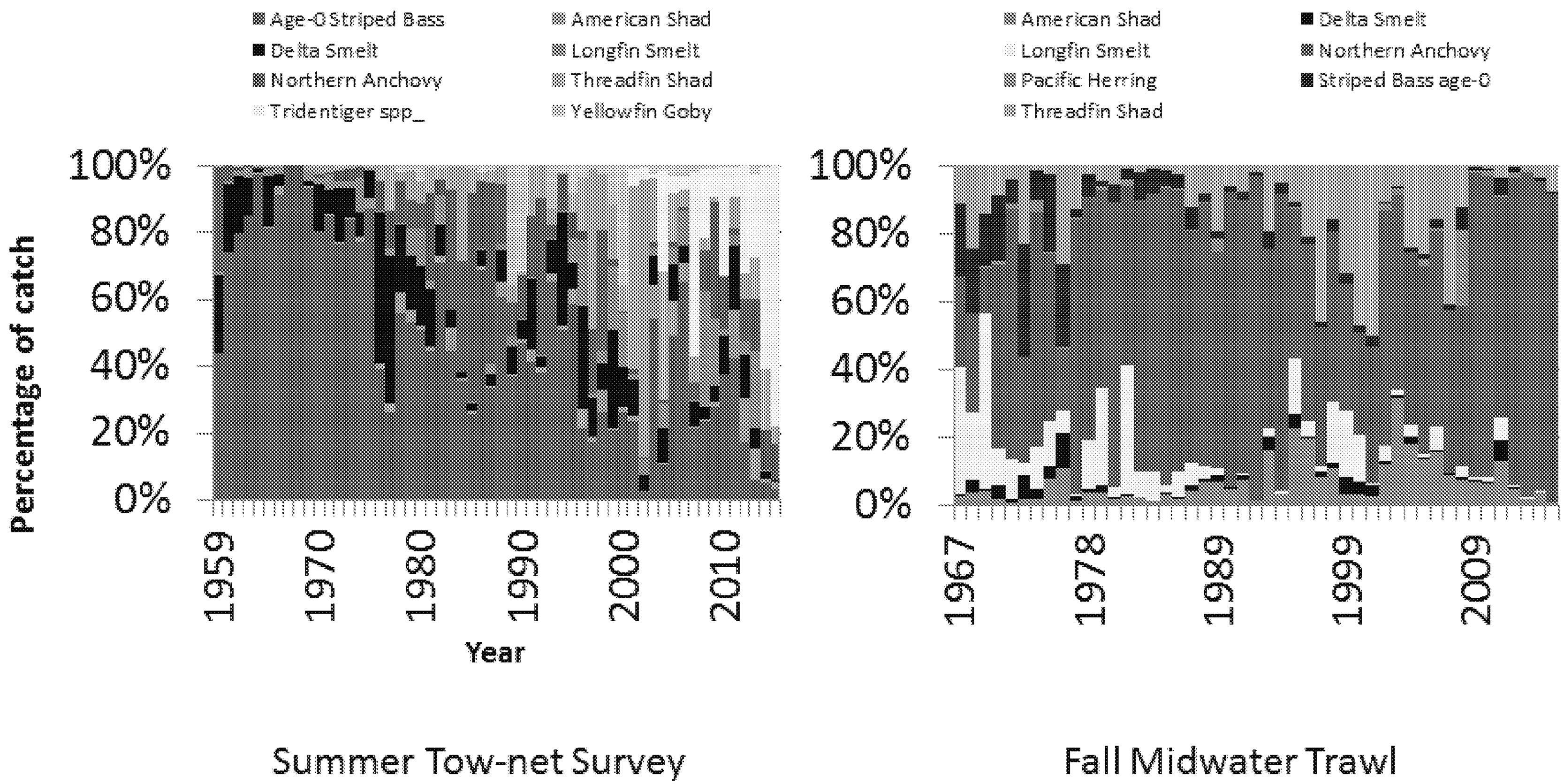

Figure 9.2.1.1-3. Fractional compositions of the eight most frequently collected fish species in the CDFW's summer TNS (1959-2015), and the seven most frequently collected fish species in the FMWT (1967-2015).

The long-term rarity of the delta smelt has had a consequence for understanding the reasons for their population decline, which generates uncertainty about how resource managers should intervene. Some pelagic fishes have shown long-term relationships between Delta inflow, Delta outflow, or X2 and their abundance or survival (Stevens and Miller 1983; Jassby *et al.* 1995; Kimmerer 2002b; Kimmerer *et al.* 2009). There does seem to be some difference in the likelihood of whether the delta smelt population will increase or decrease in abundance from one year to the next based on hydrology (Figure 9.2.1.1-4), but there has never been any predictable relationship linking freshwater flow conditions to the relative abundance of delta smelt (Stevens and Miller 1983; Jassby *et al.* 1995; Kimmerer 2002b; Kimmerer *et al.* 2009). Recently, several teams of researchers have built several varieties of conceptual (IEP 2015) and mathematical (Thomson *et al.* 2010; Maunder and Deriso 2011; Miller *et al.* 2012; Rose *et al.* 2013a) life cycle models for the delta smelt that attempt to describe the reasons the population has declined. Some of these models have been able to recreate the trend observed in abundance indices very well (Figure 9.2.1.1-5), but they have all done so using different approaches and different variables to do so. Collectively, these modeling efforts have been helpful in that they generally support water temperature and changes in the estuary's food web as 'universally supported' factors affecting delta smelt. However, they have also come to very different conclusions about the conservation value of more readily manageable factors like water project operations.

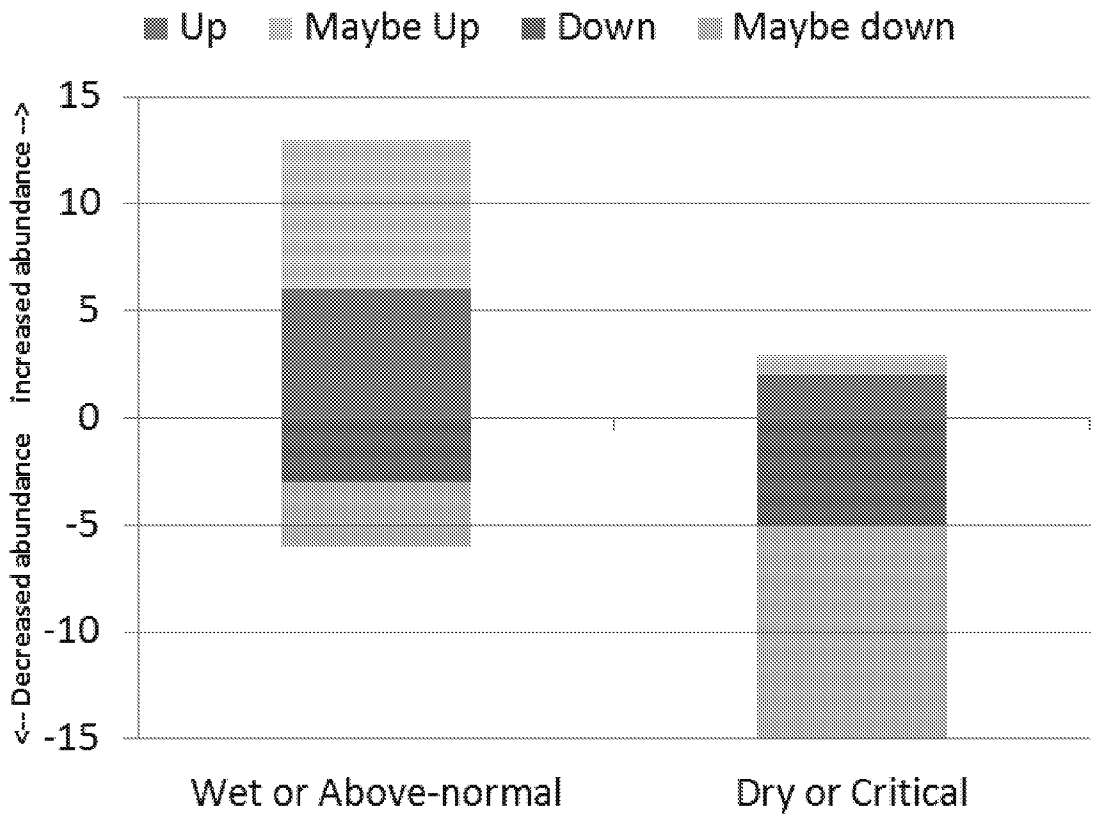

Figure 9.2.1.1-4. Frequencies of delta smelt population increases or decreases (red colored portions of each bar occurring below zero) based on the CDFW's FMWT Survey, 1967-2015. A population increase reflects an increase in relative abundance over the prior year's index and a population decrease reflects a decrease in relative abundance compared to the prior year's index. The Service performed bootstrap resampling on each year's catch per tow to generate a mean catch per tow with 95 percent confidence intervals. This resulted in four possible outcomes: (1) a statistically significant increase in relative abundance from one year to the next in which the confidence intervals of the two years did not overlap ("Up"; solid blue bar segments), (2) a statistically non-significant increase in relative abundance from one year to the next in which the confidence intervals of the two years overlapped ("Maybe Up"; lighter blue bar segments), (3) a statistically significant decrease in relative abundance from one year to the next in which the confidence intervals of the two years did not overlap ("Down"; solid red bar segments), or (4) a statistically non-significant decrease in relative abundance from one year to the next in which the confidence intervals of the two years overlapped ("Maybe Down"; lighter red bar segments). The counts in each of the four categories were combined by Sacramento Valley WY types except that below-normal years were not plotted. The frequencies of population decline were converted into a negative number so that population increases would count up from the zero line on the y-axis and population decreases would count down from the zero line.

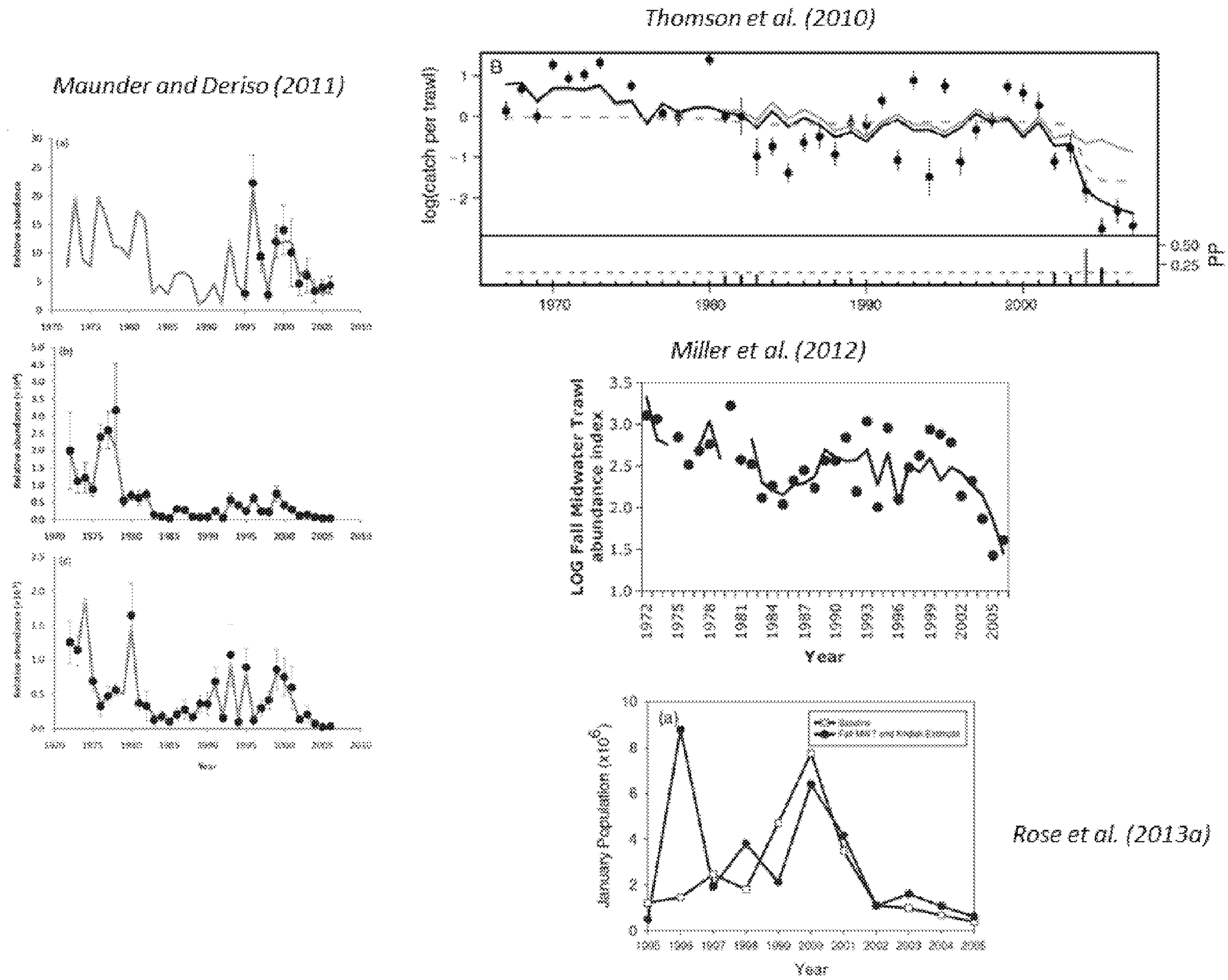

Figure 9.2.1.1-5. Examples of recent published model fits to time series of delta smelt relative abundance data. The source of each is referenced above or alongside each time series. In each plot, observed catches are depicted as black dots and model predictions of the data as gray or black lines. Model predictions from Rose *et al.* (2013a) are a black line with open symbols. In Maunder and Deriso (2011), the three panels represent the 20-mm Survey, summer TNS, and FMWT Survey from top to bottom, respectively. The other three studies are fit to estimates of adult delta smelt relative abundance (FMWT catch in Thomson *et al.* 2010 and the FMWT index in Miller *et al.* 2012) or absolute abundance (Rose *et al.* 2013a). See each study for further details on Methods, Results, and the authors' interpretations of their results.

Habitat and Distribution

Because the delta smelt only lives in part of one comprehensively monitored estuary, its general distribution is well understood (Moyle *et al.* 1992; Bennett 2005; Hobbs *et al.* 2006, 2007; Feyrer *et al.* 2007; Nobriga *et al.* 2008; Kimmerer *et al.* 2009; Merz *et al.* 2011; Murphy and Hamilton 2013; Sommer and Mejia 2013). There are both location-based (*e.g.*, Sacramento River around Decker Island) and conditions-based (low-salinity zone) habitats that delta smelt permanently occupy. There are habitats that delta smelt occupy seasonally (*e.g.*, for spawning), and there are habitats that delta smelt occupy transiently, which we define here as occasional seasonal use. These include distribution extremes from which delta smelt are not collected every year or even in most years.

Most delta smelt complete their entire life cycle within or immediately upstream of the estuary's low-salinity zone. The low-salinity zone is frequently defined as waters with a salinity range of about 0.5 to 6 parts per thousand (ppt) (Kimmerer 2004). The 0.5 to 6 ppt and similar salinity ranges reported by different authors were chosen based on analyses of historical peaks in phytoplankton and zooplankton abundance, but recent physiological and molecular biological research has indicated that the salinities that typify the low-salinity zone are also optimal for delta smelt (Komoroske *et al.* 2016). The low-salinity zone is a dynamic habitat with size and location that respond rapidly to changes in tidal and river flows. The U.S. Environmental Protection Agency (EPA) recently finished a comprehensive set of maps that show how the low-salinity zone changes in size and shape when freshwater flows change the location of X2[19]. The low-salinity zone expands and moves downstream when river flows into the estuary are high, placing low-salinity water over a larger and more diverse set of nominal habitat types than occurs under low flow conditions. During periods of low outflow, the low-salinity zone contracts and moves upstream. Due to its historical importance as a fish nursery habitat, there is a long research history into the physics and biology of the San Francisco Estuary's low-salinity zone (Kimmerer 2004).

The ecological function of the low-salinity zone also varies depending mainly on freshwater flow (Jassby *et al.* 1995; Kimmerer 2002a; Kimmerer 2004). Low outflow can decrease the capacity of the low-salinity zone and adjacent habitats to support the production of delta smelt by reducing habitat diversity and concentrating the fish with their predators and competitors (Service 1993, 1994). During the past four decades, the low-salinity zone ecosystem has undergone substantial changes in turbidity (Schoellhamer 2011) and food web function (Winder and Jassby 2011) that cannot be undone solely by increasing Delta outflow. These habitat changes, which extend into parts of the Delta where water is fresher than 0.5 ppt, have also decreased the ability of the low-salinity zone and adjacent habitats to support the production of delta smelt (Thomson *et al.* 2010; Rose *et al.* 2013b; IEP 2015).

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[19]http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_Delta/docs/cmnt081712/karen_schwinn.pdf

Delta smelt have been observed as far west as San Francisco Bay, as far north as Knights Landing on the Sacramento River, as far east as Woodbridge on the Mokelumne River and Stockton on the Calaveras River, and as far south as Mossdale on the San Joaquin River (Figure 9.2.1.1-6). This distribution represents a range of salinity from essentially zero ppt up to about 20 ppt, which represents a salinity range well beyond definitions of the low-salinity zone or mixing zone near a salinity of 2 ppt emphasized in the critical habitat rule (Service 1994). It is also well beyond the geographic extent of the critical habitat rule (described below). However, most delta smelt that have been collected in the extensively surveyed San Francisco Estuary have been collected from locations within the bounds defined in the critical habitat rule. In addition, all habitats known to be occupied year-around by delta smelt occur within the bounds defined in the critical habitat rule.

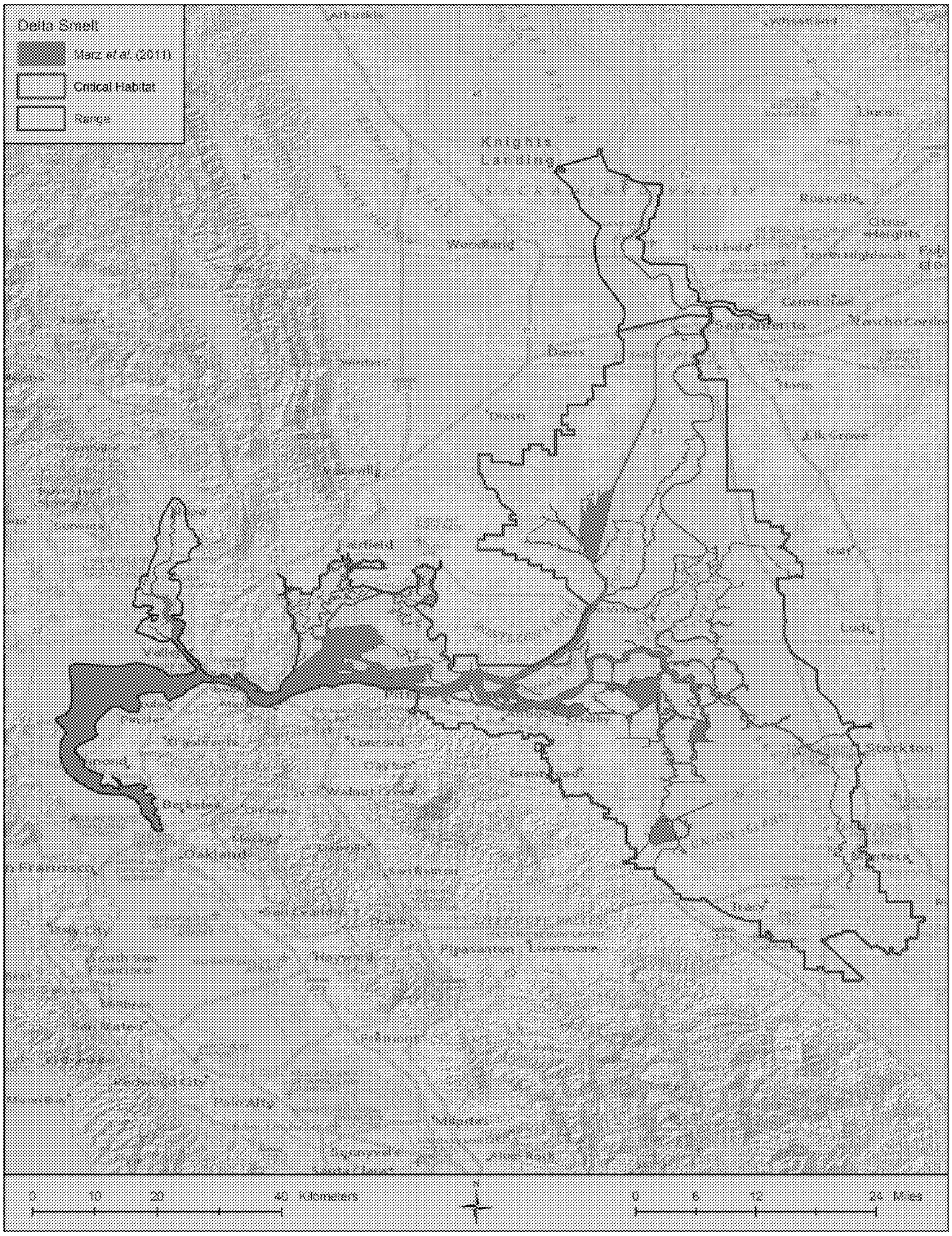

Figure 9.2.1.1-6. Delta smelt range map. Waterways colored in purple depict the delta smelt distribution described by Merz *et al.* (2011). The Service has used newer information to expand the transient range of delta smelt further up the Napa and Sacramento rivers than indicated by Merz *et al.* (2011). The red polygon depicts the designated critical habitat for the delta smelt.

Delta smelt permanently occupy the Cache Slough 'Complex', including Liberty Island and the adjacent reach of the Sacramento Deepwater Shipping Channel (Sommer and Mejia 2013), Cache Slough to its confluence with the Sacramento River and the Sacramento River from that confluence downstream to Chipps Island, Honker Bay, and the eastern part of Montezuma Slough (Figure 9.2.1.1-7). The reasons delta smelt are believed to permanently occupy this part of the estuary are the year-round presence of fresh- to low-salinity water that is comparatively turbid and of a tolerable water temperature. These appropriate water quality conditions overlap an underwater landscape featuring variation in depth, tidal current velocities, edge habitats, and food production (Sweetnam 1999; Nobriga *et al.* 2008; Feyrer *et al.* 2011; Murphy and Hamilton 2013; Hammock *et al.* 2015; Bever *et al.* 2016). Field observations are increasingly supported by laboratory research that explains how delta smelt respond physiologically to variation in salinity, turbidity, water temperature, and other aspects of their habitat that can vary with changes in climate, freshwater flow and estuarine bathymetry (Hasenbein *et al.* 2014; 2016; Komoroske *et al.* 2014; 2016).

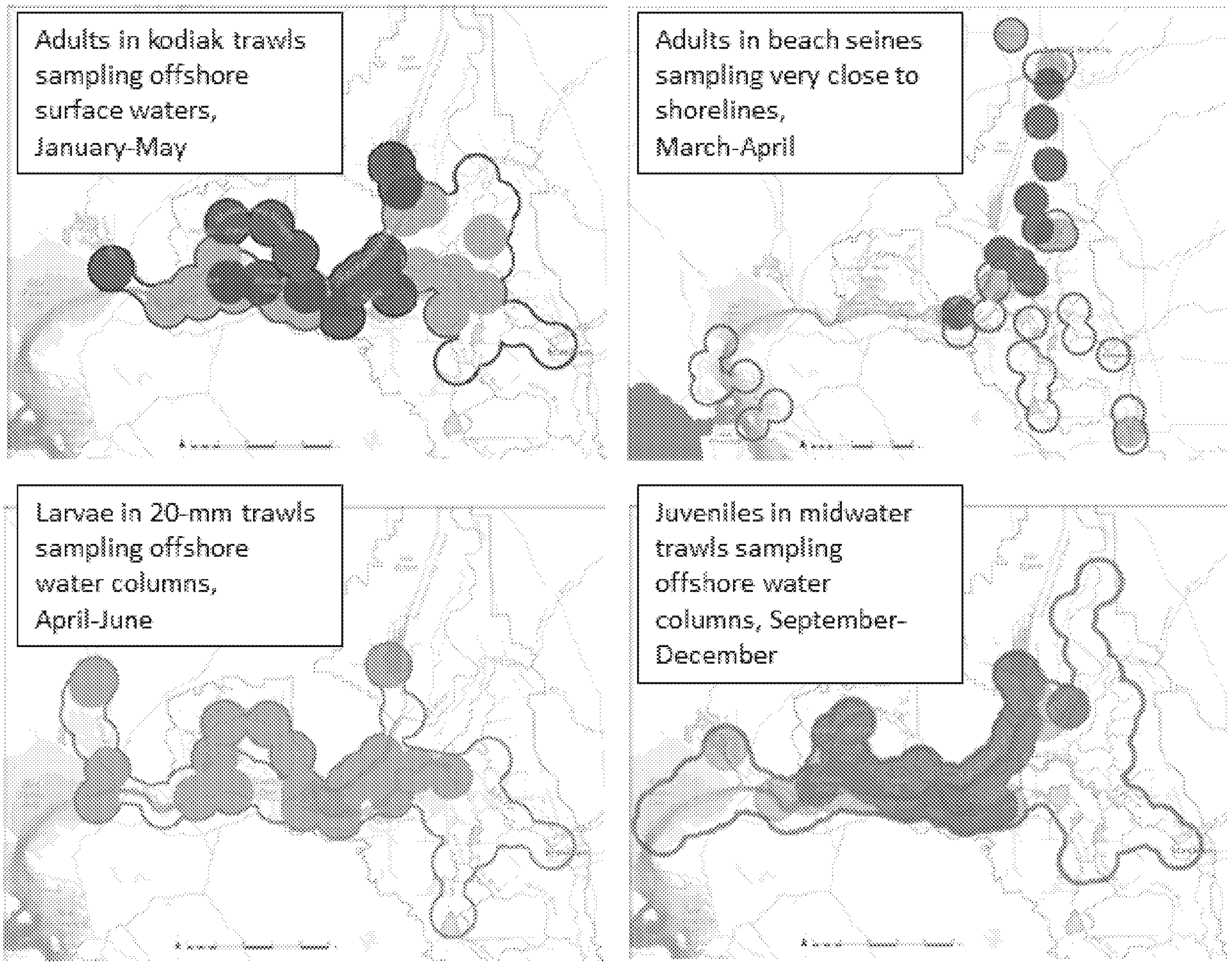

Figure 9.2.1.1-7. Maps of multi-year average distributions of delta smelt collected in four monitoring programs. The sampling regions covered by each survey are outlined. The areas with dark shading surround sampling stations in which 90 percent of the delta smelt collections occurred, the areas with light shading surround sampling stations in which the next 9 percent of delta smelt collections occurred. Source: Murphy and Hamilton (2013).

Each year, the distribution of delta smelt seasonally expands when adults disperse in response to winter flow increases that also coincide with seasonal increases in turbidity and decreases in water temperature (Figure 9.2.1.1-7). The annual range expansion of adult delta smelt extends up the Sacramento River to about Garcia Bend in the Pocket neighborhood of Sacramento, up the San Joaquin River from Antioch to areas near Stockton, up the lower Mokelumne River system, and west throughout Suisun Bay and Suisun Marsh. Some delta smelt seasonally and transiently occupy Old and Middle river in the south Delta each year, but face a high risk of entrainment when they do (Grimaldo *et al.* 2009).

The distribution of delta smelt occasionally expands beyond this area (Figure 9.2.1.1-6). For instance, during high outflow winters, adult delta smelt also disperse west into San Pablo Bay and up into the Napa River (Hobbs *et al.* 2007). Similarly, delta smelt have occasionally been reported from the Sacramento River north of Garcia Bend up to Knights Landing (*e.g.*, Merz *et al.* 2011; Vincik and Julienne 2012).

The expanded adult distribution initially affects the distribution of the next generation because delta smelt eggs are adhesive and not believed to be highly mobile once they are spawned. The distribution of larvae reflects a combination of where spawning occurred and freshwater flow conditions when the eggs hatched. Variation in Delta outflow affects the spatial distribution of the delta smelt population for most of its life. The ecological condition of the estuary's low-salinity zone has historically been indexed using a statistic called X2, a local name for the geographic location of 2 ppt salinity near the bottom of the water column (Jassby *et al.* 1995). During spring, larval delta smelt have centers of distribution in freshwater, typically 20-40 km upstream of X2 (Dege and Brown 2004). By July, as water temperatures in the Delta reach annual peaks, post-larval and juvenile delta smelt have centers of distribution very close to X2 (Dege and Brown 2004), but the fish are broadly distributed around that peak (Sweetnam 1999; Nobriga *et al.* 2008). During the fall, subadult delta smelt still have a center of distribution near X2 (Sommer *et al.* 2011), and remain broadly distributed around that peak (Feyrer *et al.* 2007; 2011). During the winter, maturing adult delta smelt disperse in connection with winter storms following the spread of turbid freshwater (Grimaldo *et al.* 2009; Sommer *et al.* 2011; Murphy and Hamilton 2013). Recent analyses suggest that after an initial dispersal in December, the adult delta smelt population does not respond strongly to variation in Delta outflow during January to May (Polansky *et al.* in press), though some individuals continue to move around in response to flow changes associated with storms (Leo Polansky, unpublished analysis of Early Warning Survey data set).

Food

At all life stages, numerous small planktonic crustaceans, especially a group called calanoid copepods, make up most of the delta smelt diet (Nobriga 2002; Slater and Baxter 2014). Small crustaceans are ubiquitously distributed throughout the estuary, but which prey species are present at particular times and locations has changed dramatically over time (Winder and Jassby 2011; Kratina *et al.* 2014). This has likely affected delta smelt feeding success, particularly during Central California's warm summers.

Reproductive Strategy

The reproductive behavior of delta smelt is only known from captive specimens spawned in artificial environments and most of the information has never been published. Spawning likely occurs mainly at night with several males attending a female that broadcasts her eggs onto bottom substrate (Bennett 2005). Although preferred spawning substrate is unknown, spawning habits of delta smelt's closest relative, the surf smelt (*Hypomesus pretiosus*), as well as unpublished experimental trials, suggest that sand may be the preferred substrate (Bennett 2005). Hatching success peaks at temperatures of 15-16°C (59-61°F) and decreases at cooler and warmer temperatures. Hatching success nears zero percent as water temperatures exceed 20°C (68°F) (Bennett 2005). Water temperatures suitable for spawning occur most frequently during the months of March-May, but ripe female delta smelt have been observed as early as January and larvae have been collected as late as July.

Delta smelt spawn in the estuary and have one spawning season for each generation, which makes the timing and duration of the spawning season important every year. As stated above, delta smelt are believed to spawn on sandy substrates in fresh and possibly low-salinity water (Bennett 2005). Therefore, freshwater flow affects how much of the estuary is available for delta smelt to spawn (Hobbs *et al.* 2007).

Delta smelt can start spawning when water temperatures reach about 10°C (50°F) and can continue until temperatures reach about 20°C (Bennett 2005). The ideal spawning condition occurs when water temperatures remain cool throughout the spring (*e.g.*, March-May). Few delta smelt ≤ 55 mm in length are sexually mature and 50% of delta smelt reach sexual maturity at 60 to 65 mm in length (Rose *et al.* 2013b). Thus, if water temperatures rise much above 10°C in the winter, the "spawning season" can start before most individuals are mature enough to actually spawn. If temperatures continue to warm rapidly toward 20°C in early spring, that can end the spawning season with only a small fraction of 'adult' fish having had an opportunity to spawn. Delta smelt were initially believed to spawn only once before dying (Moyle *et al.* 1992). It has since been confirmed that like many other ecologically similar forage fishes (Winemiller and Rose 1992), individual delta smelt can spawn more than once if water temperatures remain suitable for a sufficient length of time, and if the adults find enough food to support the production of another batch of eggs (Lindberg *et al.* 2013; Kurobe *et al.* 2016). As a result, the longer water temperatures remain cool, the more fish have time to mature and the more times individual fish can spawn.

Although adult delta smelt can spawn more than once, mortality is high during the spawning season and most adults die by May (Polansky *et al.* in press). The egg stage averages about 10 days before the embryos hatch into larvae. The larval stage averages about 30 days. Metamorphosing "post-larvae" appear in monitoring surveys from April into July of most years. By July, most delta smelt have reached the juvenile life stage. Delta smelt collected during the fall are called "subadults", a stage which lasts until winter when fish disperse toward spawning habitats. This winter dispersal usually precedes sexual maturity (Sommer *et al.* 2011).

Recovery and Management

Following Moyle *et al.* (1992), the Service (1993) indicated that SWP and CVP exports were the primary factors contributing to the decline of delta smelt due to entrainment of larvae and juveniles and the effects of low flow on the location and function of the estuary mixing zone (now called the low-salinity zone). In addition, prolonged drought during 1987-1992, in-Delta water diversions, reduction in food supplies by nonindigenous aquatic species, specifically overbite clam and nonnative copepods, and toxicity due to agricultural and industrial chemicals were also factors considered to be threatening the delta smelt. In the 2008 Service BiOp, the Service's Reasonable and Prudent Alternative required protection of delta smelt from entrainment in December through June and augmentation of Delta outflow during the fall of Wet or Above-Normal years as classified by the State of California (Service 2008). The expansion of entrainment protection for delta smelt in the 2008 Service BiOp was in response to large increases in juvenile and adult salvage in the early 2000s (Kimmerer 2008). The fall X2 requirement was in response to increased fall exports that had resulted in greatly reduced variability in Delta outflow during the fall months (Feyrer *et al.* 2011).

Consistent with the 2008 Service BiOp, the Service's (2010c) recommendation to uplist delta smelt from threatened to endangered included reservoir operations and water diversions upstream of the estuary as mechanisms interacting with exports to restrict the low-salinity zone and concentrate delta smelt with competing fish species. In addition, Brazilian waterweed (*Egeria densa*) and increasing water transparency were considered new detrimental habitat changes. Predation was considered a low-level threat linked to increasing waterweed abundance and increasing water transparency. Additional threats considered potentially significant by the Service in 2010 were entrainment into power plant diversions, contaminants, and reproductive problems that can stem from small population sizes. Conservation recommendations included: establish Delta outflows proportionate to unimpaired flows to set outflow targets as fractions of runoff in the Central Valley watersheds; minimize reverse flows in Old and Middle river; and, establish a genetic management plan with the goals of minimizing the loss of genetic diversity and limiting risk of extinction caused by unpredictable catastrophic events. The Service (2012b) added climate change to the list of threats to the delta smelt.

Continued protection of the delta smelt from excessive entrainment, improving the estuary's flow regime, suppression of nonnative species, increasing zooplankton abundance, and improving water quality are among the actions needed to recover the delta smelt.

Climate Change

Climate projections for the San Francisco Bay-Delta and its watershed indicate that temperature and precipitation changes will diminish snowpack in the Sierra-Nevada, changing the timing and availability of natural water supplies (Knowles and Cayan 2002; Dettinger 2005). Warming may result in more precipitation falling as rain which will mean less water stored in spring snowpacks. This would increase the frequency of rain-on-snow events and increase winter runoff with an associated decrease in runoff for the remainder of the year (Hayhoe *et al.* 2004). Overall, these and other storm track changes may lead to increased frequency of flood and drought cycles during the 21st century (Dettinger *et al.* 2015). Thus far, the 21st century has been substantially drier than the 20th century (Figure 9.2.1.1-8) to which the frequency of WY type classifications are compared.

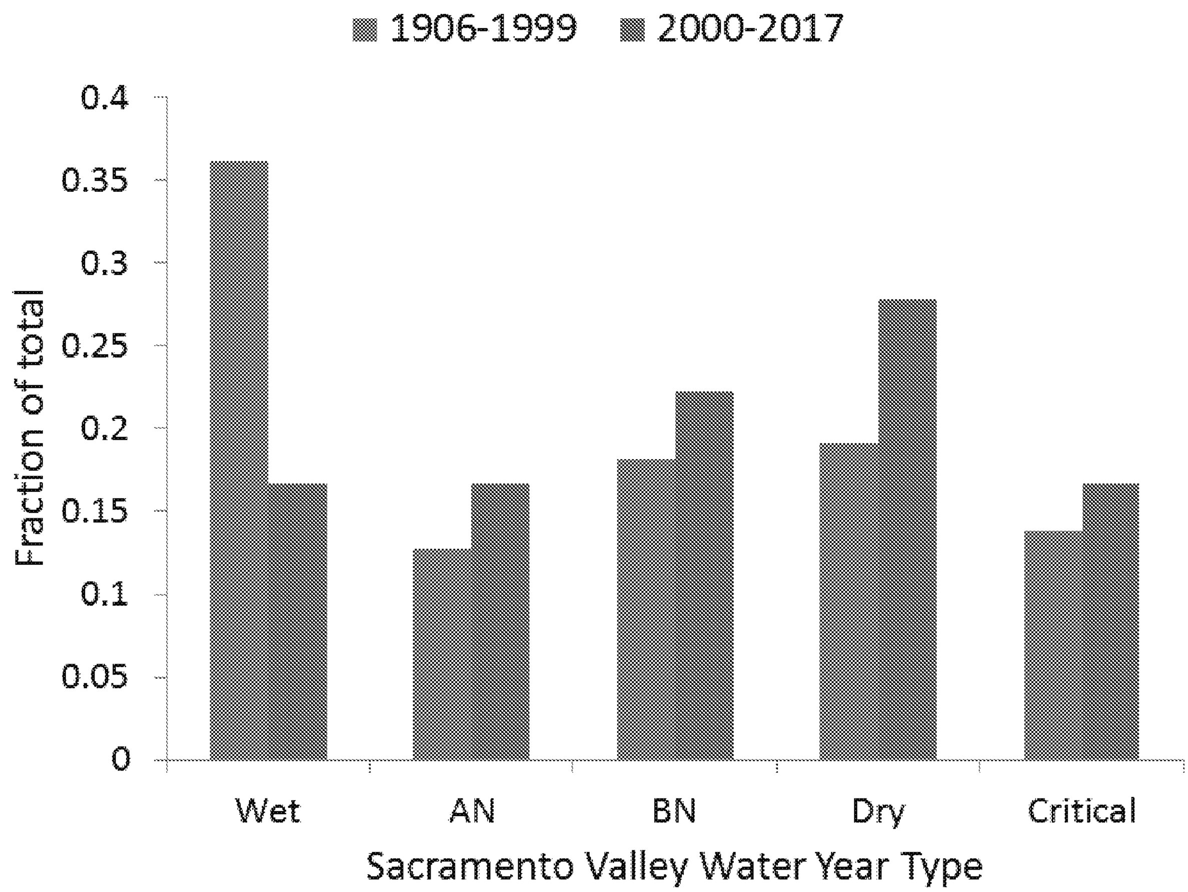

Figure 9.2.1.1-8. Frequency distribution of Sacramento Valley WY types for: blue=1906-1999 and red=2000-2017.

Sea level rise is also anticipated as a consequence of a warming global climate and if it is not mitigated, sea level rise will likely influence saltwater intrusion into the Bay-Delta. Salinity within the northern San Francisco Bay is projected to rise by 4.5 ppt by the end of the century (Cloern *et al.* 2011). Elevated salinity could push X2 further eastward in the estuary if outflows are not increased to compensate. Fall X2 mean values are projected to increase by about 7 km to the area near the City of Antioch approximately 90 km from the Golden Gate Bridge by 2100 (Brown *et al.* 2013). This projected change in the location of X2 in the fall is expected to decrease suitable physical habitat if current levees and channel structures are maintained.

Central California's warm summers are already a source of energetic stress for delta smelt and warm springs already severely compress the duration of their spawning season (Rose *et al.* 2013a,b). Central California's climate is anticipated to get warmer (Dettinger 2005). We expect warmer estuary temperatures to present a significant conservation challenge for delta smelt. Mean annual water temperatures within the Delta are expected to increase steadily during the second half of this century (Cloern *et al.* 2011). Warmer water temperatures could further reduce delta smelt spawning opportunities, decrease juvenile growth during the warmest months, and increase mortality via several food web pathways including: increased vulnerability to predators, increased vulnerability to toxins, and decreased capacity for delta smelt to successfully compete in an estuary that is energetically more optimal for warm-water tolerant fishes.

Recent research into the ecological effects of warming water temperatures suggests that delta smelt, depending on location, may be forced to spawn an average of ten to twenty-five days earlier in the season (Brown *et al.* 2013). The number of high mortality days (cumulative number of days of daily average water temperature >25°C (77°F) is expected to increase (Brown *et al.* 2013). The number of physiologically stressful days (cumulative number of days of daily average water temperature >20°C (68°F) is expected to be stable or decrease partly because many stressful days will become high mortality days. Thus, current modeling indicates that delta smelt will likely face a shorter maturation window and reduced habitat availability due to increased water temperatures. A shorter maturation window will likely have effects on reproduction (Brown *et al.* 2013). Growth rates have been shown to slow as water temperatures increase above 20°C (68°F), requiring delta smelt to consume more food to reach growth rates that are normal at lower water temperatures (Rose *et al.* 2013a). Delta smelt are smaller, on average, than in the past (Sweetnam 1999; Bennett 2005) and expected temperature increases due to climate change will likely slow growth rates further.

In summary, the delta smelt is currently at the southern limit of the inland distribution of the family Osmeridae along the Pacific coast of North America. Thus, increased temperatures associated with climate change may present a significant conservation challenge if they result in a Bay-Delta that is outside of the delta smelt's competitive limits. For the time being however, water temperatures are cool enough in the delta smelt's range for the species to complete its life cycle.

Summary of the Status of Delta Smelt

The relative abundance of delta smelt has reached very low numbers for a small forage fish in an ecosystem the size of the San Francisco Estuary. The extremely low recent relative abundance reflects decades of habitat change and marginalization by non-native species that prey on and out-compete delta smelt. The anticipated effects of climate change on the San Francisco Estuary and watershed such as warmer water temperatures, greater salinity intrusion, lower snowpack contribution to spring outflows from the Delta, and the potential for frequent extreme drought, which has been experienced for the 21st century thus far (Figure 9.2.1.1-8) indicate challenges to delta smelt survival will increase. A rebound in relative abundance during the very wet and cool conditions during 2011 indicated that delta smelt retained some population resilience (IEP 2015). However, since 2012, declines to record low population estimates (Table 9.2.1.1-1) have been broadly associated with the remarkably dry hydrology occurring from 2012 to 2016.